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PROBLEMS OF AUTOMATION OF INDUSTRIAL PROCESSES  
- USSR -

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## FOREWORD

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## PROBLEMS OF AUTOMATION OF INDUSTRIAL PROCESSES

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Following is a translation of an article by A. Lerner in the Promshleno-Ekonomicheskaya Gazeta (Industrial-Economic Newspaper), Moscow, 13 December 1959, page 4.

Like an endless band, the pipe moves out of the mill on the outgoing roller path. The operator squeezes the handle of the rheostat, his gaze riveted to the glowing stripe of the seam being welded; but not the seam is beginning to lose its color: orange hues have appeared in the yellow-white coloration. That means that the temperature of the weld has fallen. The seam may turn out not to have been welded completely and the pipe will be rejected.

The operator quickly turns the handle of the rheostat, increasing the voltage of the welding generator. The seam immediately brightens. But isn't there danger of overheating? The pipe will also be rejected. Not the slightest alteration escapes the eyes of the operator, not only in the brightness and coloration of the luminous stripe of the seam, but also in the working of the mechanisms. He evaluates all this and then makes the decisions on how to set up and maintain the procedure by which maximum productivity and high quality of weld is attained.

It seems that the automation of the operation of such a complex process is impossible. It is difficult to conceive of an automation capable of determining the operating procedures of a mill and to control the process under rapidly changing conditions. Actually, the cyclical systems of automatic regulation usually employed are not able to control such complex processes effectively. Indeed, all control operations in such a system must be provided in advance, and the problem of control consists only in the fulfillment of the established cycle of operation by the mechanism. The control of the mill with the help of a feedback is possible only in case the temperature of the seam is measured in the same seat of the weld and instantly reacts to all of its deviations. However, the construction of the mill permits the measurement of the temperature of the seam only from some distance from the seat of the weld, and that means a time lag in the movement of the pipe from the place of welding to the place of measurement. Consequently, it is impossible to correct the welding procedure according to the deviation in temperature of the seam at the place of measurement since the control signal would be formed with a big lag and could in a number of cases worsen the procedure.

Nevertheless it is possible to solve the control problem of the pipe welding mill. To that end it is necessary to make use of both these principles and of some new ones, which permit the creation of a self-regulating control system for the process.

Such a system if constructed in the following manner: The power of the welding current is automatically stabilized by the use of a feedback system. It alters the voltage of the welding generator in case of deviation of the current from the set rate. The set rate of welding current automatically alters in conformity with the changing thickness of the metal, which is measured while in motion for rate of absorption of X-rays by the metal.

Just as it is possible to change the thickness of the strip only to the moment that it is turned into pipe, so is the signal which represents the thickness received long in advance of the moment that the measured section of the strip arrives at the seat of welding. Therefore, it is necessary to introduce a mechanism which retains that signal and reproduces it exactly at that moment when the corresponding section of the strip arrives at the place where the seam is made. Precisely at that moment the welding current regulator is given the task of maintaining a rate of current which corresponds to the thickness of the given section of the strip. The retention of the signal of thickness is accomplished here by means of a record of the current of varying frequency on a tape recorder.

But the operating conditions of the mill change so much that it will not be possible to establish a definite relationship once and for all between the thickness of the metal and the rate of welding current. Therefore the control system assembly, which gives the order of an operating change to the welding current regulator by a signal which represents the thickness of the strip, must be re-set often.

A new problem arises - the automatic adjustment of the characteristics of the control system into conformity with the changing operating conditions of the controlled object. Systems in which such problems are solved are regarded as one of the classes of self-regulating systems.

In this case automatic setting of the system is achieved with the help of a mechanism called a correlative analyser. By means of the statistical processing of signals representing the deviation in the thickness of the metal and the deviation in the temperature of the seam, this mechanism reveals the degree of insufficiency or overage of the assigned setting to the welding current regulator and according to that re-sets the communication assembly between the thickness of the strip and the setting of the welding current regulator. Thanks to that, the control system is gradually "taught" to respond correctly to the changes in the thickness of the strip. If the operating conditions of the mill change, and the previous response no longer ensures a good stabilization of the welding temperature, the control system automatically "re-learns" and begins anew to respond to the changes in thickness, until the most efficient setting is again found. Such a control system was developed in the Institute of Automation and Telemechanics of the Academy of Sciences of

the USSR and installed in the Moscow pipe plant. It raised the quality of manufactured pipes greatly and freed the operators from fatiguing and may also be applied to the automatic regulation of sizes of metals in rolling mills and to certain chemical production.

Often during automation of one or another installation arises the problem of the automatic determination of an operational procedure under which several indices maintain the most efficient (maximum or minimum) level. We encounter such problems, for example, during the automation of air furnaces in which the process of combustion is conducted so that the necessary amount of heat is obtained with the consumption of the minimum quantity of fuel, and in various kinds of chemical production, and so forth.

Presently we have at our disposal two methods for solving problems of that sort. The first of them is that the control system, on the basis of information about operating conditions, calculates the significance of the indices representing the most efficient procedure and establishes the procedure in conformance with the calculated indices.

Of course, such a method of automatic establishment of the most efficient procedure is possible only in the event that we know with sufficient exactness for practical purposes the relationships of the optimum procedure to the controlled operating conditions of the installation. In such cases where the relationships are unknown, the optimum procedure of the controlled object was subjected to insignificant change the whole time. Depending upon whether the index of effectiveness improves or becomes worse, the system chooses the direction of further changes of procedure. In this manner the system will continue to maintain the optimum procedure.

The simplest example of a self-regulating system of such sort is the extreme regulator for the regulation of combustion in air furnaces, for automatic tuning of radio transmitters, for the automatic supervision of chemical processes, and so forth.

In more complicated cases the necessity arises of automatic selection of the most efficient procedure by the influence not only over one, but over several regulating organs. So, the most efficient procedure of the rectification column is determined basically with the significance of the temperature and the expenditure of the basic product while maintaining definite conditions in the quality of production. Under these conditions the selection of the most efficient procedure becomes, of course, substantially more complicated. However, modern methods of control permit the solving not only of such, but even much more complicated problems.

At the present time machines have been created (automatic optimizers (optimizer) in the Institute of Automation and Telemechanics of the Academy of Sciences, which can effectively find the most efficient procedure while maintaining up to 12 indices while observing a new limiting conditions.

The shortcoming of self-regulating systems, the operation of which is based on the automatic selection of the most efficient procedure, appears to be that the process of selection can sometimes last too long.

Therefore, the prospect appears to be the creation of self-regulating systems combining within themselves the principle of automatic selection with the principle of establishment of the most efficient procedure on the basis of known relationships.

The further development of self-regulating systems, apparently, will take the path of the creation of self-teaching systems of control. In systems of that kind, the most efficient system, once determined, will be stored in the retaining mechanisms. And if conditions arise similar to those which have already appeared in the system, the system will be able to establish the needed procedure based on the data retained in the memory, that is, by association.

Thereupon the system by automatic selection will make the most efficient procedure more precise and alter in the memory the previously determined procedure to a new level of exactness, then more and more modern procedures and more expedient methods of control will be accumulated in the "memory." That means that a process takes place similar to that which occurs in the brain of a human while learning to operate some sort of equipment.

Such control systems possess the advantage, as compared with existing systems, that they will continuously accumulate control experience within themselves, that this experience can be preserved as long as it is convenient, and can easily be transferred to analogical mechanisms by simple reproduction of the reserve of information accumulated in the retaining mechanism. The structure of such systems is already understood, the technical means for their realization are on hand; their creation and practical utilization - is a matter for the near future.